

Shadow Flicker Impact Analysis for the Ashtabula III Wind Energy Center

Prepared for
Ashtabula Wind III, LLC

Prepared by



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ATTACHMENT

Attachment A Detailed Summary of WindPro Shadow Flicker Analysis Results

1.0 OVERVIEW

A wind turbine's moving blades can cast a moving shadow on locations within a certain distance of a turbine. These moving shadows are called shadow flicker, and can be a temporary phenomena experienced by people at nearby residences or public gathering places. The impact area depends on the time of year and day (which determines the sun's azimuth and altitude angles) and the wind turbine's physical characteristics (height, rotor diameter, blade width, and orientation of the rotor blades). Shadow flicker generally occurs during low angle sunlight conditions, typically during sunrise and sunset times of the day. However, when the sun angle gets very low (less than 3 degrees), the light has to pass through more atmosphere and becomes too diffused to form a coherent shadow. Shadow flicker will not occur when the sun is obscured by clouds or fog, at night, or when the source turbine(s) are not operating.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. Shadow flicker intensity for receptor-to-turbine distances beyond 1,500 meters is very low and generally considered imperceptible. Shadow flicker intensity for receptor-to-turbine distances between 1,000 and 1,500 meters (between 3,281 and 4,921 feet) is also low and considered barely noticeable. At this distance shadow flicker intensity would only tend to be noticed under conditions that would enhance the intensity difference, such as observing from a dark room with a single window directly facing the turbine casting the shadow. At distances less than 1,000 meters (3,281 feet), shadow flicker may be more noticeable. In general, the largest number of shadow flicker hours, along with greatest shadow flicker intensity, occurs nearest the wind turbines.

Ashtabula Wind III, LLC is proposing to install 43 wind turbines as part of the Ashtabula III Wind Energy Center (Project) in Barnes County, North Dakota. Since the Project is using a minimum turbine siting setback requirement of 1,400 feet (from any occupied residence), sensitive receptors (occupied residences) are generally not located in the worst case potential shadow flicker impact zones, which ensures that shadow flicker impacts are minimized.

The wind turbine being considered for the Project, and evaluated for potential shadow flicker impacts, has the following characteristics:

- **GE Wind Energy GE xle** – 3-blade 82.5-meter-diameter rotor, with a hub height of 80 meters. The GE xle has a nominal rotor speed of 18 rpm which translates to a blade pass frequency of 0.9 Hz (less than 1 alternation per second).

Shadow flicker frequency is related to the wind turbine's rotor blade speed and the number of blades on the rotor. From a health standpoint, such low frequencies are harmless. For comparison, strobe lights used in discotheques have frequencies which range from about 3 Hertz (Hz) to 10 Hz (1 Hz = 1 flash per second). As a result, public concerns that flickering light from wind turbines can have negative health effects, such as triggering seizures in people with epilepsy are unfounded. The Epilepsy Action (working name for the British Epilepsy Foundation), states that there is no evidence that wind turbines can cause seizures (Epilepsy

Action 2008). However, they recommend that wind turbine flicker frequency be limited to 3 Hz. Since the proposed Project's wind turbine blade pass frequency is approximately 0.9 Hz (less than 1 alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

Shadow flicker impacts are not regulated in applicable state or federal law, and there is no permitting requirement with regard to hours per year of anticipated impacts to a receptor from a wind energy project. Due to the significant growth of the wind energy industry in recent years, some states have published model bylaws for local governments to adopt or modify at their own discretion which sometimes includes guidance and recommendations for shadow flicker levels and mitigation. However, a general precedent has been established in the industry both abroad and in the United States that fewer than 30 hours per year of shadow flicker impacts is acceptable to receptors in terms of nuisance and well below health hazard thresholds. In a German court case for example, a judge found 30 hours of actual shadow flicker per year at a certain neighbor's property to be tolerable (WindPower 2003).

2.0 WINDPRO SHADOW FLICKER ANALYSIS

An analysis of potential shadow flicker impacts from the Project was conducted using the WindPro software package. The turbine array dated May 13, 2010, which includes 43 planned turbine locations, was included in the analysis.

In addition to the proposed Project turbines, there are 131 existing wind turbines from the Ashtabula I Wind Energy Center that are located immediately south and east of the Ashtabula III Project Area. These existing turbines have also been taken into account in the shadow flicker analysis. Existing wind turbines from the Ashtabula II Wind Energy Center were also considered. However, these turbines are located too far away (over 3,000 meters to the north) from Ashtabula III related receptors to contribute any shadow flicker impact. Potential shadow flicker impacts from the Ashtabula II project were evaluated separately. Results for this analysis were submitted under separate cover in June 2009.

The WindPro analysis was conducted to determine shadow flicker impacts under realistic impact conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors out to 1,500 meters (4,921.3 feet). The realistic impact condition scenario is based on the following assumptions:

- The elevation and position geometries of the wind turbines and surrounding receptors (houses). Elevations were determined using USGS digital elevation model (DEM) data. Positions geometries were determined using GIS and referenced to UTM Zone 14 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute-by-minute basis over the course of a year.
- Historical sunshine hours availability (percent of total available). Historical sunshine rates for the area (as summarized by the National Climatic Data Center (NCDC, 2008) for nearby Fargo, ND) used in this analysis are as follows:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50%	56%	58%	60%	61%	62%	71%	69%	60%	54%	40%	43%

- Estimated wind turbine operations and orientation [based on approximately 1.5 years of data from April 2, 2007 to October 16, 2008 of on-site measured wind data (wind speed / wind direction frequency distribution)]. The WindPro calculated wind direction frequency distribution for operating hour winds is as follows:

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
7.7%	5.2%	6.2%	5.1%	7.8%	10.3%	8.9%	9.0%	6.5%	8.4%	12.8%	12.1%

- Receptor viewpoints (i.e., house windows) are assumed to always be directly facing turbine to sun line of sight (“greenhouse mode”).

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun’s path with respect to each turbine location is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon were excluded, for the reasons identified earlier in this section.

A total of 142 sensitive receptor locations were identified in the vicinity of the Project Area. These receptors are based on the April 9, 2010 Farmstead Report, and supplementary input from the client based on local knowledge. These locations correspond to houses or other structures in the Project Area. In addition, non-residential receptors (such as a church, cemetery, and abandoned farm yards) were considered. A receptor in the model is defined as a 1 m² area (approximate size of a typical window), 1 meter (3.28 feet) aboveground level. Approximate eye level is set at 1.5 meters (4.94 feet). Figure 1 shows the sensitive receptor locations included in the analysis.

3.0 WINDPRO SHADOW FLICKER ANALYSIS RESULTS

WindPro predicts that shadow flicker impacts will primarily occur near the wind turbines. Figure 2 illustrates the WindPro predicted expected shadow flicker impact areas. A detailed WindPro shadow flicker analysis results summary, for each of the modeling receptor locations, is provided in Attachment A. Table 1 presents the WindPro predicted expected shadow flicker impacts for the ten receptors with the highest number of predicted shadow hours. Only 1 of the 142 receptors modeled had expected shadow flicker impacts predicted for more than 30 hours per year, and this was a non-residential receptor (farm outbuilding).

Only seven of the top ten impacted receptors are actively occupied structures. The maximum predicted shadow flicker impact at any actively occupied receptor (#20046) is 28 hours, 3 minutes per year, which is approximately 0.6 percent of the potential available daylight hours.

Table 1. WindPro Predicted Shadow Flicker Impacts for Receptors with Maximum Impacts

Receptor ID	Status	Shadow Hours per Year (expected) [hh:mm / year]
730009	Non-Residential	36:43
20046	Occupied	28:03
1224	Occupied	27:13
1237	Occupied	26:53
1235	Non-Residential	26:33
1219	Occupied	25:33
1209	Unoccupied	23:27
1232	Occupied	22:52
1233	Occupied	21:50
20113a	Occupied	21:25

Approximately 99.3 percent, or 142 of the 143 receptor locations evaluated, have less than 30 hours per year of predicted shadow flicker impact. The shadow flicker impact prediction statistics are as summarized in Table 2.

Table 2. Statistical Summary of WindPro Predicted Shadow Flicker Impacts at Modeled Sensitive Receptor Locations

Cumulative Shadow Flicker Time (expected)	Number of Receptors
Total	142
= 0 Hours	19
> 0 Hours < 10 hours	91
≥ 10 Hours < 20 hours	18
≥ 20 Hours < 30 hours	13
≥ 30 Hours < 40 hours	1
≥ 40 hours	0

4.0 CONCLUSION

The analysis of potential shadow flicker impacts from the Project on nearby houses (receptors) shows that shadow flicker impacts within the area of study are expected to be minor. The analysis assumes that the houses all have a direct in line view of the incoming shadow flicker sunlight and does not account for trees or other obstructions which may block sunlight. In reality, the windows of many houses will not face the sun directly for the key shadow flicker impact times. In addition, potential shadow flicker impacts for wind turbines up to 1,500 meters (4,921 feet) away were determined. In reality, the shadow flicker impacts for turbines beyond 1,000 meters (3,281 feet) will be very low intensity. For these reasons, shadow flicker impacts are expected to be less than estimated with the conservative analysis, and shadow flicker is not expected to be a significant environmental impact.

Finally, there is no state or federal regulatory threshold for shadow flicker hours per year at a given receptor; therefore, the Project in no way violates state or federal permitting requirements or conditions according to the results of this shadow flicker impact analysis.

5.0 REFERENCES

Epilepsy Action. 2008. British Epilepsy Association.

http://www.epilepsy.org.uk/info/photo_other.html. Accessed 3/1/10.

WindPower 2003. Danish Wind industry Association. Shadow Casting From Wind Turbines.

<http://guidedtour.windpower.org/en/tour/env/shadow/index.htm>, Accessed 4/28/10

National Climatic Data Center. 2008. – Sunshine Average Percent of Possible.

<http://www.ncdc.noaa.gov/oa/climate/online/ccd/pctpos.txt> . Accessed 3/1/10

FIGURE 1
SENSITIVE RECEPTORS MODELED
WITH WINDPRO TO PREDICT
EXPECTED SHADOW FLICKER IMPACTS

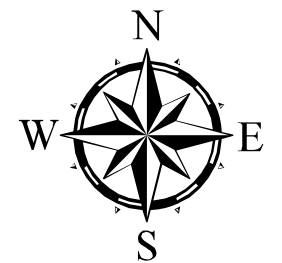
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Legend

- As-Built Ashtabula I Turbine Location (10-21-2008 Layout)
 - Planned Ashtabula III Turbine Location (5-13-2010 Layout)
- Receptor (based on 4-9-2010 Farmstead Report)
- Occupied
 - Unoccupied
 - Non-Residential



REFERENCE MAP

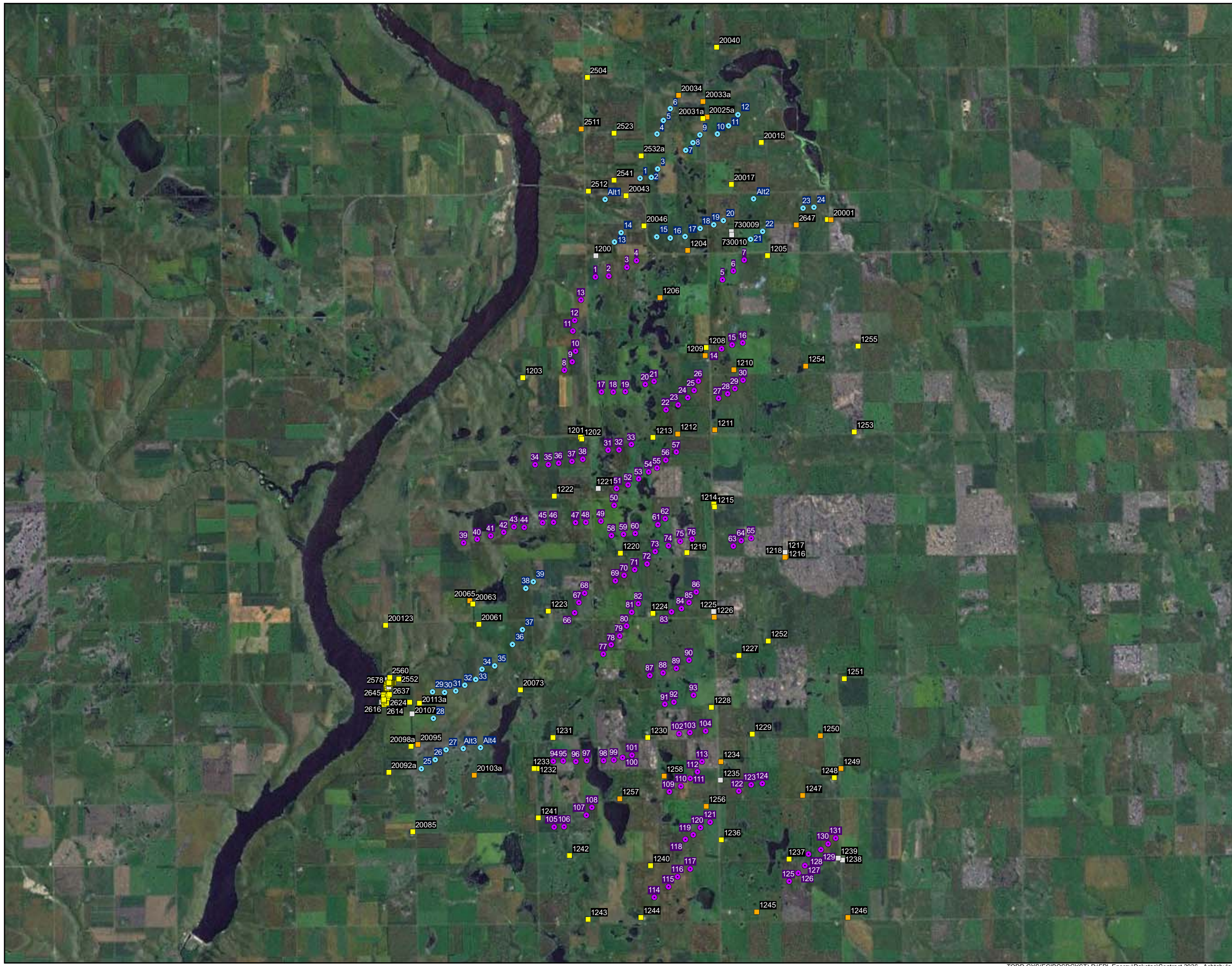


FIGURE 2
WINDPRO PREDICTED EXPECTED
SHADOW FLICKER IMPACT AREAS

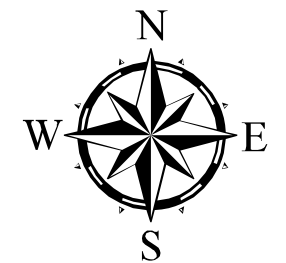
JUNE 2010



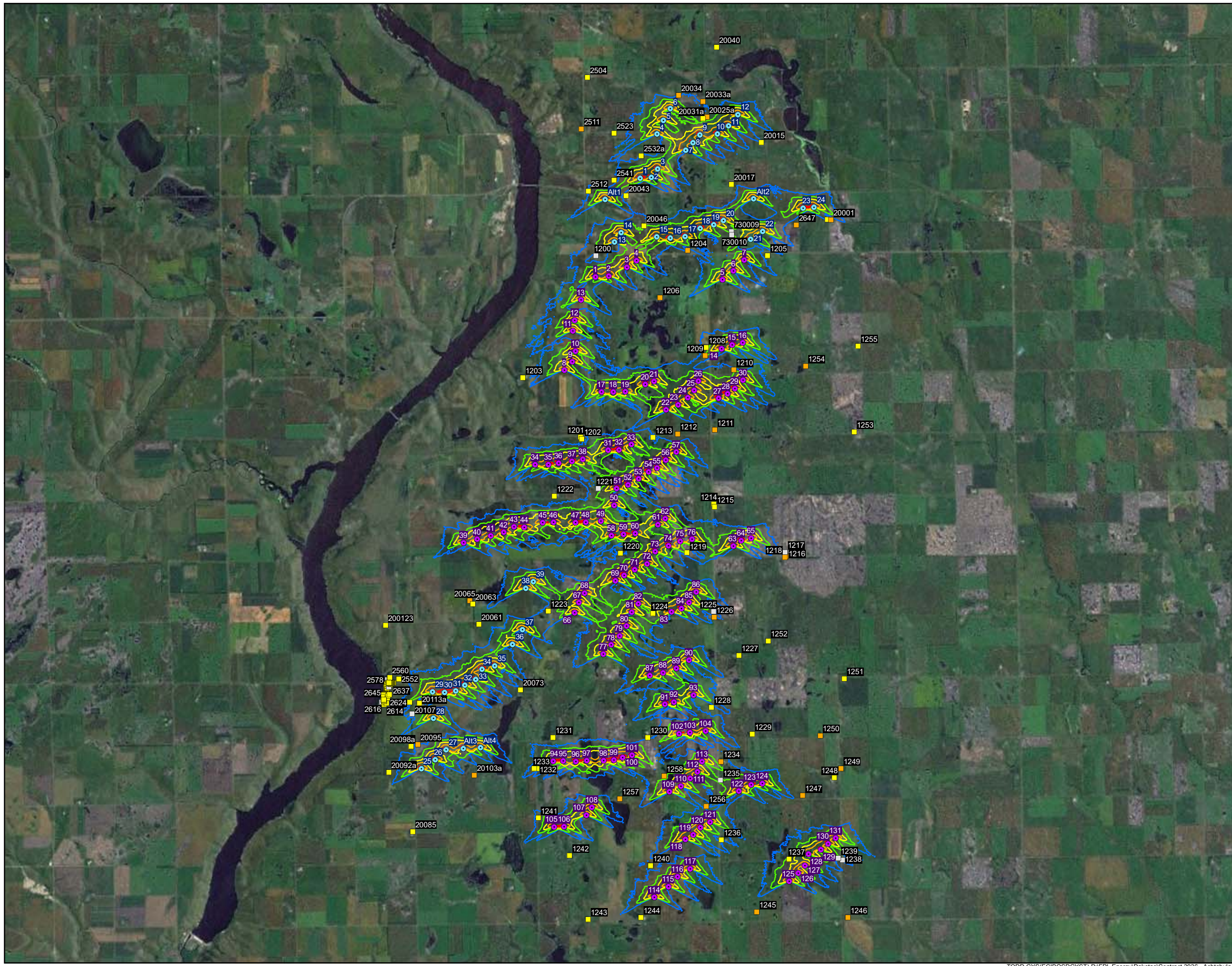
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Legend

- As-Built Ashtabula I Turbine Location (10-21-2008 Layout)
- Planned Ashtabula III Turbine Location (5-13-2010 Layout)
- Receptor (based on 4-9-2010 Farmstead Report)
 - Occupied
 - Unoccupied
 - Non-Residential
- Shadow Flicker Iso Line
 - 10 hrs/yr
 - 25 hrs/yr
 - 50 hrs/yr
 - 100 hrs/yr
 - 200 hrs/yr



REFERENCE MAP



ATTACHMENT A

Detailed Summary of WindPro Shadow Flicker Analysis Results

Ashtabula III Wind Energy Center WindPro Shadow Flicker Analysis Results Summary

Ash III Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)	Receptor Status
730009	584,152	5,228,183	36:43:00	Non-Residential
20046	581,828	5,228,336	28:03:00	Occupied
1224	582,065	5,218,050	27:13:00	Occupied
1237	585,678	5,211,517	26:53:00	Occupied
1235	583,860	5,213,618	26:33:00	Non-Residential
1219	582,973	5,219,659	25:33:00	Occupied
1209	583,452	5,224,891	23:27:00	Unoccupied
1232	578,990	5,213,918	22:52:00	Occupied
1233	578,911	5,213,927	21:50:00	Occupied
20113a	575,864	5,215,660	21:25:00	Occupied
1221	580,613	5,221,365	21:04:00	Non-Residential
1239	586,985	5,211,550	20:53:00	Non-Residential
20114	575,604	5,215,682	20:41:00	Occupied
730010	584,153	5,228,099	20:11:00	Non-Residential
1234	583,866	5,214,102	18:28:00	Unoccupied
1258	582,358	5,213,729	18:25:00	Unoccupied
20031a	583,396	5,231,195	17:58:00	Occupied
1210	584,213	5,224,515	17:33:00	Unoccupied
1208	583,479	5,225,107	17:16:00	Occupied
1238	587,097	5,211,492	17:06:00	Non-Residential
1241	579,021	5,212,612	14:52:00	Occupied
1223	579,281	5,218,105	14:25:00	Occupied
20025a	583,499	5,231,233	13:52:00	Unoccupied
1225	583,675	5,218,098	13:25:00	Non-Residential
20004	586,700	5,228,506	12:42:00	Occupied
20095	575,821	5,214,562	12:27:00	Unoccupied
2532a	581,751	5,230,201	12:20:00	Occupied
2512	580,352	5,229,261	11:09:00	Occupied
20107	575,670	5,215,379	10:52:00	Non-Residential
20015	584,944	5,230,556	10:28:00	Occupied
1213	582,065	5,222,720	10:05:00	Occupied
20001	586,797	5,228,499	10:05:00	Unoccupied
1216	585,599	5,219,562	9:31:00	Unoccupied
1220	581,199	5,219,641	9:06:00	Occupied
20073	578,543	5,216,011	8:53:00	Occupied
20033a	583,394	5,231,641	8:50:00	Unoccupied
1204	582,984	5,227,692	8:24:00	Unoccupied
1218	585,566	5,219,542	8:10:00	Unoccupied
1226	583,688	5,217,946	7:59:00	Unoccupied
20034	582,746	5,231,810	7:50:00	Unoccupied
20098a	575,645	5,214,511	7:49:00	Occupied
1230	581,932	5,214,743	7:44:00	Occupied
1236	583,887	5,212,028	7:26:00	Occupied
2541	581,032	5,229,560	7:21:00	Occupied

Ash III Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted	Receptor Status
			Expected Shadow Flicker (Hours per Year)	
1202	580,174	5,222,682	7:14:00	Occupied
1217	585,575	5,219,664	7:04:00	Non-Residential
1205	585,112	5,227,553	7:03:00	Occupied
1256	583,481	5,212,919	7:02:00	Unoccupied
1201	580,142	5,222,727	6:28:00	Occupied
20043	581,353	5,229,137	6:15:00	Occupied
1257	581,183	5,213,115	5:45:00	Unoccupied
20017	584,151	5,229,447	5:35:00	Occupied
1228	583,623	5,215,544	5:25:00	Occupied
1240	582,004	5,211,346	5:11:00	Occupied
2647	585,869	5,228,361	4:35:00	Unoccupied
1222	579,442	5,221,153	4:16:00	Occupied
20092a	575,047	5,213,822	4:07:00	Occupied
1200	580,550	5,227,542	4:03:00	Non-Residential
20061	577,437	5,217,759	3:59:00	Occupied
2626	575,064	5,215,887	3:57:00	Occupied
2552	575,315	5,216,300	3:56:00	Occupied
2523	581,033	5,230,798	3:37:00	Occupied
2627	575,052	5,216,092	3:20:00	Non-Residential
2622	575,012	5,215,797	3:16:00	Occupied
1203	578,609	5,224,306	3:15:00	Occupied
2624	575,025	5,215,851	3:12:00	Occupied
20103a	577,321	5,213,745	3:11:00	Unoccupied
1247	586,041	5,213,209	3:03:00	Unoccupied
2585	574,992	5,216,020	2:52:00	Occupied
2588	574,997	5,215,981	2:52:00	Occupied
2589	575,003	5,215,974	2:52:00	Occupied
2592	574,986	5,215,925	2:52:00	Occupied
2579	574,980	5,216,082	2:51:00	Occupied
2584	574,988	5,216,024	2:51:00	Occupied
2594	574,976	5,215,917	2:50:00	Occupied
2596	574,959	5,215,909	2:48:00	Occupied
2582	574,982	5,216,050	2:47:00	Occupied
2631	575,174	5,216,204	2:47:00	Occupied
1231	579,412	5,214,742	2:44:00	Occupied
2608	574,910	5,215,827	2:41:00	Occupied
2598	574,939	5,215,898	2:39:00	Occupied
2632	575,149	5,216,203	2:38:00	Occupied
2602	574,909	5,215,871	2:37:00	Occupied
2600	574,914	5,215,892	2:36:00	Occupied
2633	575,136	5,216,206	2:35:00	Occupied
2634	575,123	5,216,202	2:32:00	Occupied
2635	575,112	5,216,192	2:29:00	Occupied
2558	575,072	5,216,320	2:28:00	Occupied
2636	575,111	5,216,170	2:25:00	Occupied
1211	583,711	5,222,922	2:23:00	Unoccupied
2556	575,062	5,216,274	2:22:00	Occupied

Ash III Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted	Receptor Status
			Expected Shadow Flicker (Hours per Year)	
20063	577,279	5,218,296	1:50:00	Occupied
2618	574,991	5,215,657	1:47:00	Occupied
2637	575,092	5,216,166	1:42:00	Occupied
2638	575,081	5,216,167	1:41:00	Occupied
2639	575,081	5,216,187	1:40:00	Occupied
2640	575,076	5,216,199	1:38:00	Occupied
2614	574,921	5,215,625	1:36:00	Occupied
2616	574,916	5,215,672	1:36:00	Occupied
2619	574,933	5,215,709	1:36:00	Occupied
2560	575,071	5,216,337	1:34:00	Occupied
2568	575,025	5,216,147	1:34:00	Occupied
2642	575,047	5,216,188	1:34:00	Occupied
2643	575,053	5,216,204	1:34:00	Occupied
2644	574,921	5,215,729	1:34:00	Occupied
2646	574,914	5,215,752	1:34:00	Occupied
2572	575,016	5,216,111	1:33:00	Occupied
2641	575,041	5,216,181	1:32:00	Occupied
2645	574,896	5,215,744	1:30:00	Occupied
2562	575,021	5,216,206	1:29:00	Occupied
2575	574,985	5,216,123	1:29:00	Occupied
2564	575,008	5,216,179	1:28:00	Occupied
2578	574,978	5,216,090	1:28:00	Occupied
2611	574,866	5,215,691	1:28:00	Non-Residential
2567	574,990	5,216,164	1:27:00	Occupied
2570	574,984	5,216,134	1:27:00	Occupied
2555	575,014	5,216,280	1:24:00	Non-Residential
1229	584,703	5,214,840	1:13:00	Occupied
1206	582,255	5,226,427	0:54:00	Unoccupied
1227	584,346	5,216,926	0:53:00	Occupied
1215	583,702	5,220,874	0:43:00	Occupied
1212	582,720	5,222,812	0:38:00	Unoccupied
1214	583,685	5,220,947	0:34:00	Occupied
1242	579,850	5,211,611	0:00:00	Occupied
1243	580,342	5,209,916	0:00:00	Occupied
1244	581,744	5,209,967	0:00:00	Occupied
1245	584,824	5,210,115	0:00:00	Unoccupied
1246	587,242	5,209,967	0:00:00	Unoccupied
1248	586,878	5,213,679	0:00:00	Occupied
1249	587,057	5,213,929	0:00:00	Unoccupied
1250	586,510	5,214,794	0:00:00	Unoccupied
1251	587,146	5,216,309	0:00:00	Occupied
1252	585,124	5,217,306	0:00:00	Occupied
1253	587,410	5,222,861	0:00:00	Occupied
1254	586,123	5,224,611	0:00:00	Unoccupied
1255	587,516	5,225,147	0:00:00	Occupied
20040	583,758	5,233,087	0:00:00	Occupied
2504	580,329	5,232,283	0:00:00	Occupied

Ash III Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)	Receptor Status
2511	580,167	5,230,913	0:00:00	Unoccupied
20065	577,200	5,218,382	0:00:00	Unoccupied
20085	575,688	5,212,243	0:00:00	Occupied
200123	574,963	5,217,729	0:00:00	Occupied